FIRE HISTORY OF THE GREAT SMOKY MOUNTAINS NATIONAL PARK: 1940 TO 1979

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FIRE HISTORY OF THE GREAT SMOKY MOUNTAINS NATIONAL PARK -

1940 TO 1979

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ABSTRACT

Fire control records were analyzed for the period 1940 to 1979 to examine the characteristics of fires in the Great Smoky Mountains National Park. Significant differences were found between man-caused and lightning-caused fires in terms of elevation, topographic position, season, origin with respect to the park boundary, frequency, and size. Fires of both types were most frequent at lower elevations, on southeast to west facing slopes, in Tennessee and in the Cades Cove Ranger District. Man-caused fires were the most frequent, with most being incendiary in nature and started by locals. A model of fire rotation in Great Smoky Mountains National Park was presented. The model predicted that even with a 20-fold increase in fire size, lightning-caused fires will probably not maintain fire dependent forest types. Suggestions to improve the fire history data base in terms of ecological interpretation were made.

INTRODUCTION

Fire is both a constructive and destructive ecological force. Destructive characteristics have often been emphasized, yet fire can have favorable impacts on nutrient cycles, soil formation, plant reproduction, animal habitat, and microclimate. Fire also influenced ecosystems long before man became concerned with fire suppression. The presence of fire dependent (or exploitive) traits illustrates the widespread and long-term nature of fire disturbance. Communities dependent on recurrent burning may develop when fires favor some species at the expense of others. Conversely, when fires are excluded, communities may often be replaced by fire intolerant assemblages.

Since 1931, the staff of Great Smoky Mountains National Park (GRSM) has protected park lands from fire. This suppression policy reflected a legitimate concern about the widespread and potentially harmful results of fires. However, in the case of wilderness management, some kinds of fires are important natural processes. By excluding these fires, man has dramatically reduced their impact.

This study characterized fires in GRSM between 1940 and 1979, a period when fire suppression was the exclusive policy. The potential character of lightning-caused fires under a "let burn" policy was also evaluated by using the 1940 to 1979 record. Since man- and lightning-caused fire have been shown to differ in character (Barden 1974), a detailed comparison was made between the two types.

STUDY AREA

The Great Smoky Mountains National Park is a 209,000 hectare preserve that was officially established in 1934. Fire protection of the park began in 1931, when the first Superintendent arrived (Campbell 1960). Since that time, the official policy has been to suppress all fires on lands within and adjacent to GRSM.

The park represents the westernmost extension of the Blue Ridge Mountains (Fenneman 1938). Topography in this region is very dissected and steep. Elevations range from 290 meters at the mouth of Abrams Creek to 2,215 meters at the top of Clingmans Dome. Most of the bedrock in GRSM is composed of Precambrian sediments of the Ocoee Series (King et al. 1968). Devonian limestone outcrops in the Cades Cove area, where it appears through erosional windows in Precambrian rocks.

The vegetational cover of GRSM is complex and diverse. Detailed descriptions are presented by DeYoung (1979), Golden (1974), Harmon (1980b), Kuykendall (1978), and Whittaker (1956). Plant species and communities have been observed to vary along gradients of topographic-moisture, elevation, and disturbance history. GRSM is estimated to contain ca. 1,600 vascular species; of that number, ca. 15 percent are woody. Forest fuels in GRSM have been examined by Harmon (1980a) and McGuiness (1958). Forest fuel distribution is primarily a function of vegetational cover, elevation, and disturbance history (Harmon 1980a). Hardwood forests generally have less fuel than coniferous forests. Fire, chestnut blight, balsam woolly aphid, southern bark beetle, ice damage, and windthrow have been observed to increase woody fuel volumes.

Numerous climatic investigations have been completed in GRSM (Shanks 1954, 1956; Smallshaw 1953; Stephens 1969). Temperature and growing season decrease with elevation. At 487 meters, the number of days above 4°C was 122, while the same statistic for 2,100 meters was 97 days. During the year the decrease in temperature ranges between 2.3°C per 1,000 meters in winter to 6.96°C per 1,000 meters in summer. July is the warmest month and February is the coldest month. Cloud cover and precipitation both increase with elevation. Precipitation is evenly distributed throughout the year, but dry periods tend to occur during April to May and September to October.

METHODS

The data used in this analysis were taken from the fire control records kept by the management staff. However, the fire control records for the years 1955 to 1959 were missing. Data from this period was taken from notes made by Dr. Larry S. Barden during a previous study. Information on elevation, aspect, and topographic position were not usually recorded in the fire control records. These data were taken from the sketch maps which accompanied most reports. The original sketch maps were transferred to 7.5 minute USGS topographic maps. Maps for fires occurring between 1955 and 1959 were transferred from the GRSM fire atlas. In some cases, a fire started at more than one point. The elevation of the origin of fires was the mean elevation in this case. If more than one aspect or topographic position characterized the locations of a fire start, then these data were omitted.

Fire control records were originally stored in a heterogeneous format. To analyze the records, the original data was transferred to a form designed by Harmon and Covell (in press). Codes for data are

described in detail by Harmon and Covell (in press) but essentially, the codes corresponded to those presently employed in keeping Department of Interior fire control records.

After the records were transcribed to the new forms, the data was keypunched onto computer cards. SAS79 (Barr et al. 1979) at the University of Tennessee Computing Center was used for statistical analysis. Procedure FREQ and procedure CORR were used to test hypotheses concerning frequency and correlation. The G-test and Chi-square test were used to test differences between man- and lightning-caused fires.

RESULTS

Fire Cause

A total of 618 fires started in or near GRSM between 1940 and 1979. The majority of these fires, both in terms of number (86.6 percent) and area burned (97.2 percent), were started by man. Slightly less than one-third of all man-caused fires were incendiary in origin (Table 3, Appendix). Smoking, debris burning and campsites were the next most important causes of man-caused fires. Only 1.1 percent of all man-caused fires were classified as of unknown origin. Permanent residents living within one mile of GRSM (locals) were judged to have started 42.9 percent of the man-caused fires (Table 4, Appendix). Visitors were the second most frequent class of people starting fires. The portion of people classified as unknown was greater than the portion of causes classified as unknown. Since the type of person was more difficult to assess than the cause, this pattern seems logical. However, cause and people statistics are both questionable concerning accuracy, since eyewitness accounts are very rare.

Origin with Respect to GRSM Boundary

The majority of man- and lightning-caused fires started within GRSM (Table 5, Appendix). However, man-caused fires were frequently associated with park boundaries. Twenty-eight percent of the fires started by man burned outside GRSM, and 12 percent started outside but burned into GRSM. In contrast, 89 percent of the lightning fires started within the park. No lightning fires were observed to start inside GRSM and then burn lands outside the park. Allowing lightning fires to burn will increase the chances of fire moving outside the park, but based on the past location of lightning fires with respect to park boundaries, this appears to be a minor problem.

Reporters of Fire

Park employees (either lookouts, patrols, or others) were responsible for reporting 55 percent of the fires started by lightning. The class "other", which includes park visitors, reported 31 percent of the lightning fires. Since there was no separate class for visitors, their importance in reporting fires was ambiguous. The role lookouts outside GRSM played in reporting man-caused fires has remained constant, while the importance of park lookouts has decreased since 1940. Since 1970, park lookouts have only reported 1.8 percent of the fires started by man. Between 1940 and 1969, this number ranged from 42 percent during the 1940's to 29 percent in the 1960's. The portion of fires reported by planned cooperators, park aircraft, and other aircraft has increased to 18 percent between 1970 and 1977. Before this period, these classes were relatively unimportant. The fraction of man-started fires reported by "others" has also increased since 1970. Between 1940

and 1969, "others" reported 33 percent of the fires, but after 1970 the percentage for this class increased to 56. There were significant differences between the Tennessee and North Carolina portions of GRSM with regard to the people reporting fires. Lookouts outside the park have been much more important in North Carolina. (NC: 21.8 percent versus TN: 0.6 percent). The "others" category was also more important in Tennessee, compared to North Carolina, and may reflect greater park access in that state.

Fire Frequency

The mean number of fires per year caused by man for the 40-year record was 13.3 (standard deviation = 10.02). Lightning caused a mean of 2.1 fires per year (standard deviation = 2.33) over the 40 years examined. High standard deviation relative to the mean indicated high variability between years. The greatest number of fires per year was 56 and occurred in 1952 (Table 6, Appendix). Both 1951 and 1966 had the least number of fires with four. Although there were 11 years without lightning fires, each year had at least one man-caused fire. The year 1952 also had the highest number of lightning fires with ten. Five or more lightning-caused fires occurred in 1940, 1947, 1952, 1954, 1956, 1957 and 1962. The 1950's was the most important decade on park record for lightning fires, while the 1970's was the least important. The greatest number of man-caused fires in a year was 47 in 1941. The year 1952 was second highest, with 46 man-caused fires. There was a very slight trend for fewer fires in the later decades. However, 1978 also had a high incidence of man-set fires. The

correlation between the number of man- and lightning-caused fires for each year was not significant and indicated that it is possible to have years with few man-caused fires and many lightning fires and vice versa. Many factors affect the abundance of fires, including precipitation, visitor activity, park policies (which affect local residents), and maintenance activities. Precipitation is probably the most important factor, but tensions between park and local residents can also be important during certain years (e.g. 1978).

Fire Size

The mean area burned by man-started fires was 17.62 hectares. Lightning-caused fires burned a mean of 3.26 hectares. The differences between causes and mean fire size were reflected by the frequency of fires in each size class (Figure 1). Class A and B fires composed 71 percent of all lightning-started fires indicating lightning fires rarely exceeded 3.9 hectares. There were two recent lightning-caused fires that were not extinguished by management. Both fires exceeded 3.9 hectares, and the largest burned 44.5 hectares on Polecat Ridge in 1976.

Class B fires composed 44 percent of the man-caused fires. The second most frequent size class was A, which composed 30 percent. Unlike the distribution of lightning-caused fires, there were occasional Class E and F fires started by man. The largest man-started fire burned 517 hectares on Chilhowee Mountain in 1947. A large portion of land burned by this fire was outside the park.

Man-caused fires were largest in the 1940's and smallest in the 1960's. Mean man-caused fire size was similar in the 1950's and

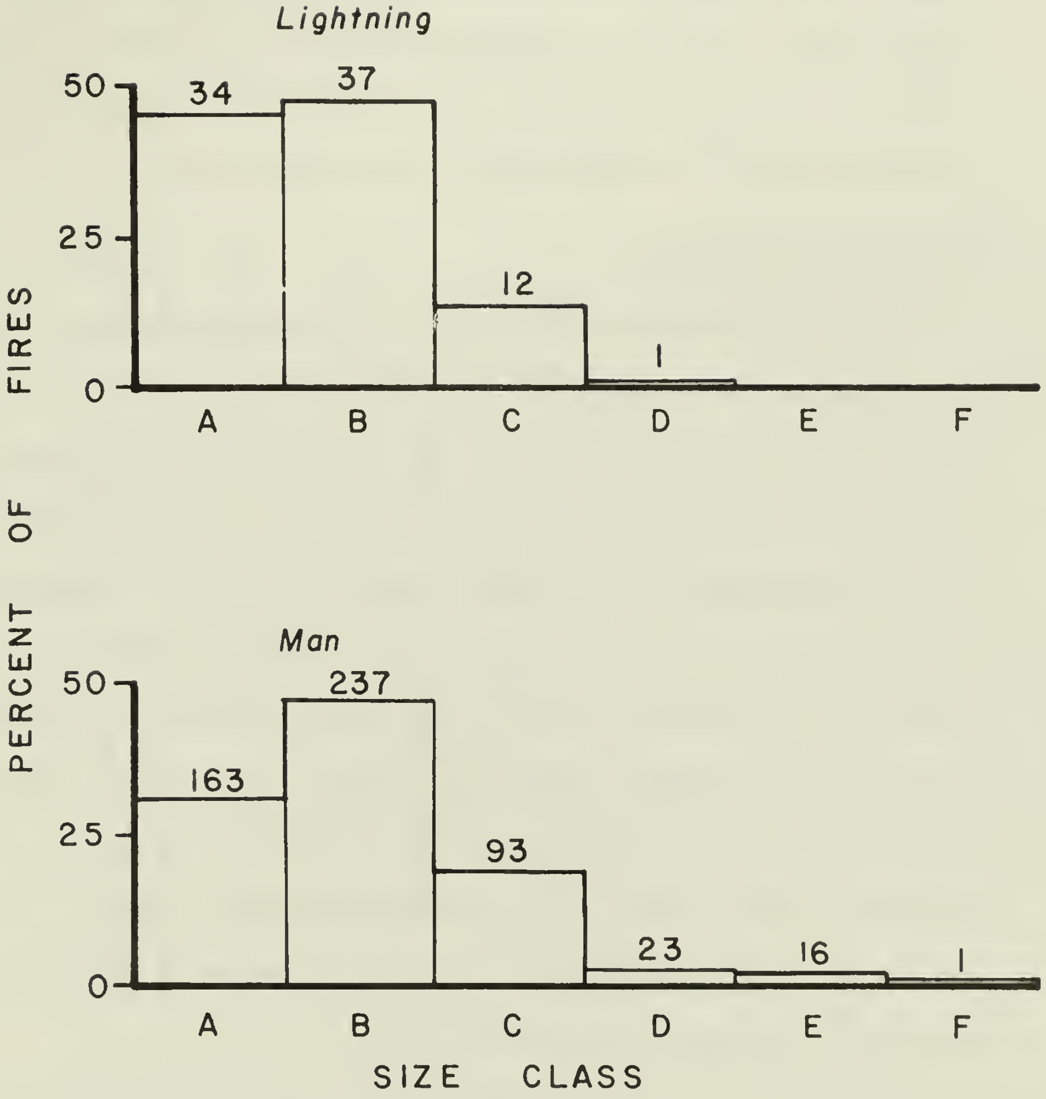

Figure 1. Distribution of man- and lightning-caused fires by size class. A = 0. - 0.1 hectares; B = 0.1 - 3.9 hectares; C = 4.0 - 40 hectares; D = 41 - 121 hectares; E = 122 - 404 hectares; F = 405 - 2025 hectares. The number above the histobar indicates the actual number of observations in that size class.

1970's. The largest mean fire size for lightning-caused fires occurred in the 1970's, while the smallest occurred in the 1940's. The larger mean in the 1970's was caused by the unofficial switch from a strict suppression policy on the Polecat Ridge fire of 1976.

Geographical Patterns

The observed number of fires in the Tennessee portion of GRSM was significantly greater than the number predicted by area alone. Between 1940 and 1979, 54 lightning-caused and 352 man-caused fires occurred in Tennessee. During the same period, 30 lightning-caused and 181 man-caused fires started in North Carolina. Since both states contain roughly the same proportion of the park, differences in man-caused fire incidents may have been related to lower accessibility and visitation in North Carolina. Bratton et al. (1979) found camper and day-hiker use was generally lower in North Carolina than in Tennessee. The larger number of lightning-caused fires in Tennessee may be due to the predominance of frontal systems originating from the west to southwest (Smallshaw 1953).

The incidence of fire also differed significantly between the 14 ranger districts (Figure 2). These differences were also significant when frequency was adjusted to reflect differences in area. Cades Cove, Cosby, Deep Creek, Sugarlands, and Tremont all had more fires than would be expected by area alone. Elkmont and Noland Creek had numbers proportional to area, while the remaining districts had fewer fires than expected by area. Cades Cove accounted for 24 (27 percent) of all lightning fires, which is roughly twice the amount predicted from area. A "let burn" policy is therefore most likely to

Figure 2. Fire incidence for ranger districts in GRSM. Each ranger district is designated by a letter code. Starting from the upper right on the map near Cosby the codes are: C - Cosby, BC - Big Creek, CT - Cataloochee, OS - Oconoluftee and Smokemont, D - Deep Creek, N - Noland Creek, F - Forney Creek, H - Hazel Creek, TM - Twenty Mile, CC - Cades Cove, T - Tremont, E - Elkmont, S - Sugarlands, G - Greenbriar.

The numerical codes indicate lightning fires/man fires, and the units are fires per year per million hectares.

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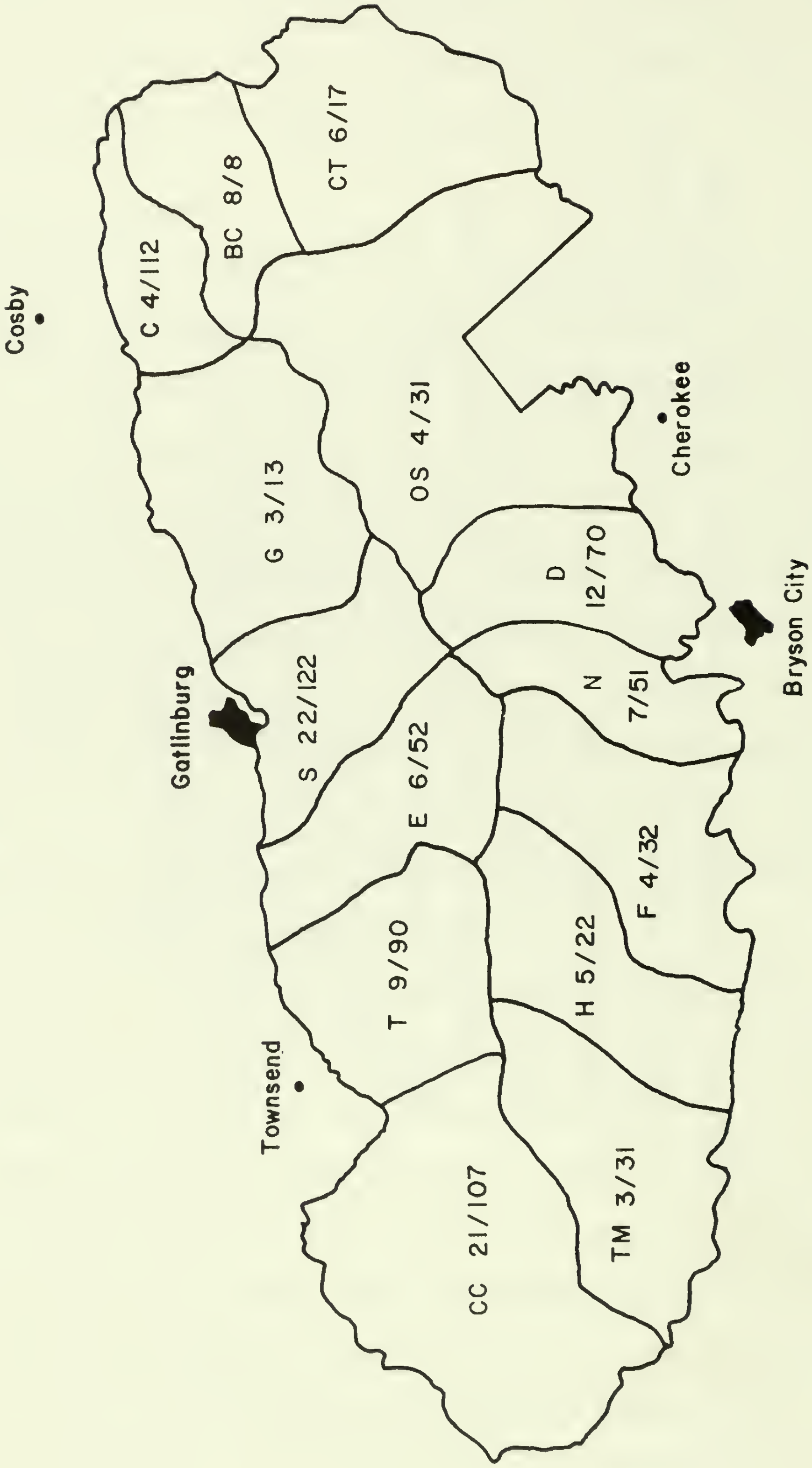
Cosby
Gatlinburg
Townsend
Cherokee
Bryson City
CT 6/17
BC 8/8
C 4/112
OS 4/31
G 3/13
D 12/70
S 22/122
N 7/51
E 6/52
F 4/32
H 5/22
T 9/90
TM 3/31
CC 21/107

influence Cades Cove and may have little impact on ranger districts such as Big Creek and Cataloochee.

Fire Season

Man- and lightning-caused fires tended to burn during different months (Figure 3). The number and area burned by man-started fires was biomodal, with a major peak in April and a minor peak in November. Winter and summer were seasons of low man-caused fire incidence. In contrast, lightning-ignited fires displayed a single peak in May. Over two-thirds of lightning-caused fires occurred in the months of April, May, and June. Lightning fires rarely occurred in the fall and winter.

Effect of Elevation

Both man- and lightning-caused fires were significantly more frequent at lower elevations than expected by area (Figure 4). The occurrence of lightning- and man-caused fires differed along the elevational gradient. Thirty-eight percent of the lightning fires started above 915 meters, but man-caused fires had only 8 percent start over this elevation. The highest portion of man-set fires originated between 305 meters and 610 meters. This pattern may have resulted from higher accessibility and activity levels at lower elevations. No fires have occurred above 1,830 meters since 1940, and fire incidence in the high elevation spruce-fir communities appears very low. As elevation increased, the total area burned also decreased, regardless of cause (Table 1).

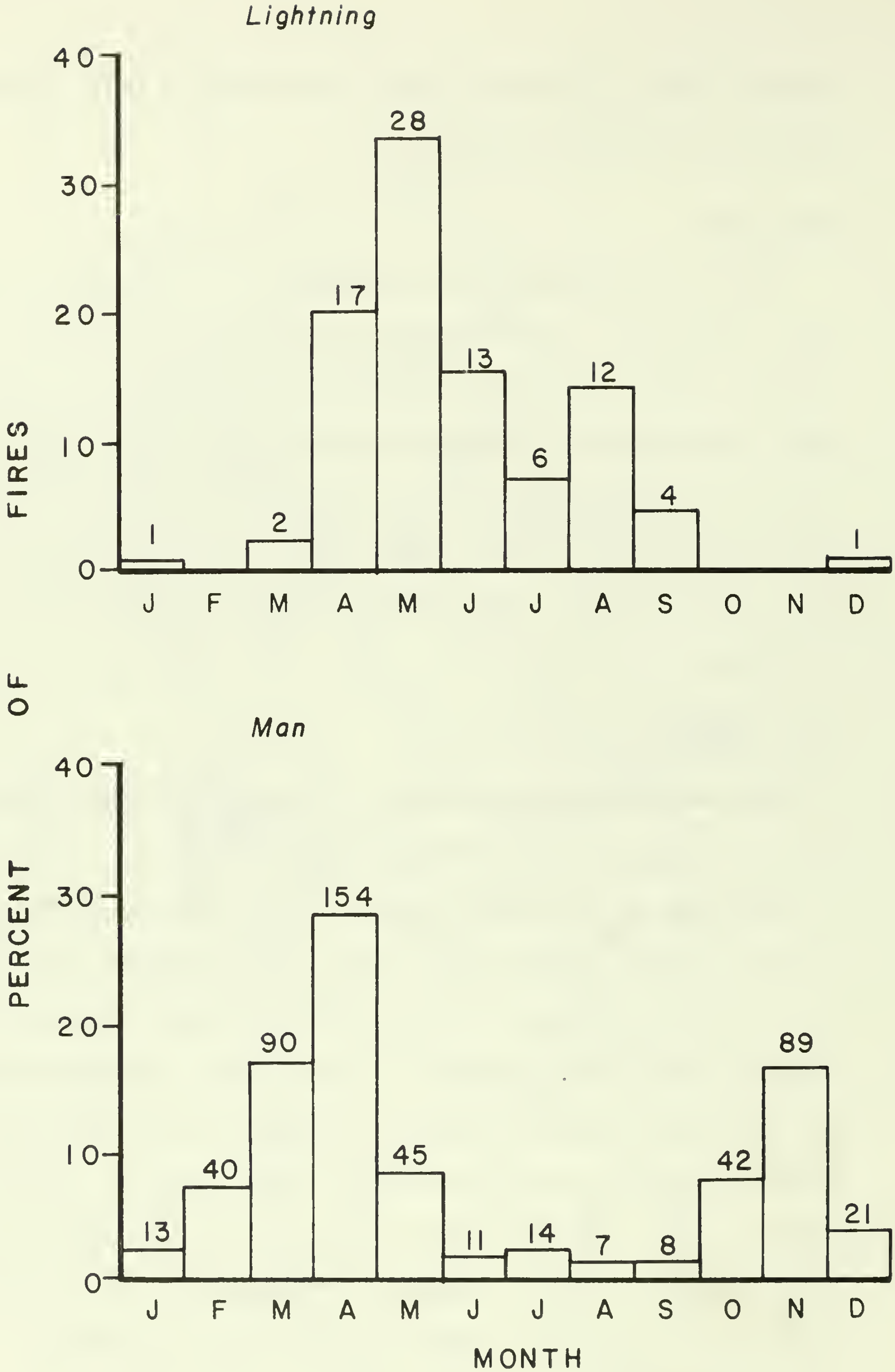

Figure 3. The distribution of man- and lightning-caused fires by month for the period 1940 to 1979. The number above the histobars represent the actual number observed.

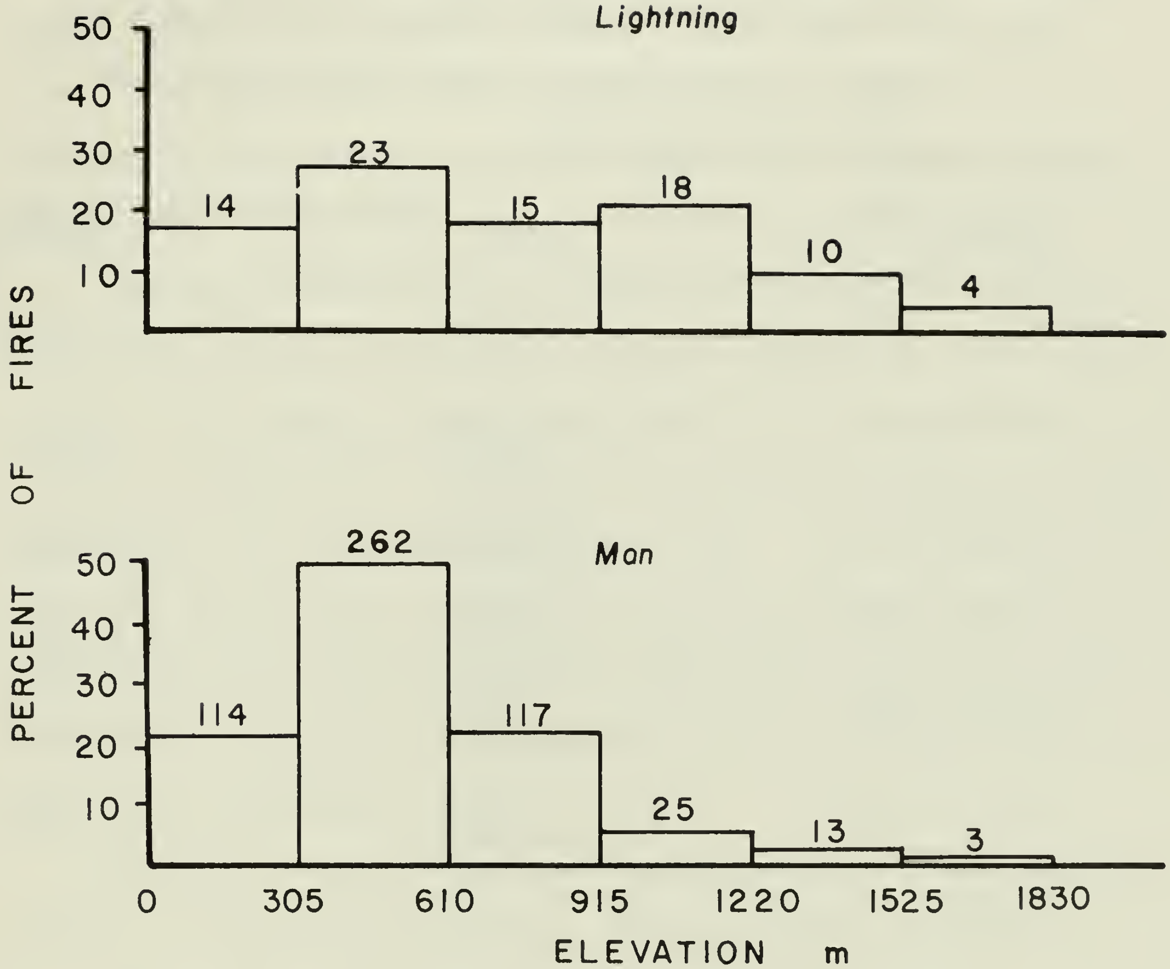

Figure 4. Origin of fires as a function of elevation for man- and lightning-caused fires. The numbers above the histobars represent the actual number of fires observed.

Table 1. Area burned by man and lightning between 1942-1979 for 305-meter elevation bands. The rotation indicates the number of years required to burn each elevation band under present fire regime

Elevation Band (meters)	Hectares burned (1942-1979)	
	Man	Lightning
0 - 305	2,997.56 (2)*	16.19 (319)*
305 - 610	4,154.05 (234)	57.35 (17,273)
610 - 915	1,347.02 (2,469)	69.70 (47,500)
915 - 1,220	884.59 (1,577)	90.19 (19,388)
1,220 - 1,525	22.61 (61,789)	40.18 34,862)
1,525 - 1,830	6.09 (77,551)	0.04 (12,666,667)
1,830 +	0 ∞	0 ∞
TOTAL	9,411.92 (844)	273.65 (30,400)

*The rotation period in years for each elevation band

Effect of Topography

Topography is divided here into aspect and topographic position. Aspect refers to the compass direction a slope faces. Topographic position in this report refers to the position with respect to a ridgetop or valley bottom. Upper one-third slopes included ridgetops, while lower one-third included valley bottoms and ravines.

Man- and lightning-caused fires were inversely related in terms of topographic position of the point of ignition (Figure 5). Sixty-three percent of the lightning-caused fires started on the upper one-third of slopes. Slightly less than half of all man-caused fires (45 percent) originated on the lower one-third of the slope. The large portion of lightning fires on upper slopes was consistent with the theory that lightning tends to strike the highest local object. The presence of roads on lower slopes may influence the origin of man-caused fires in terms of topographic position.

Man- and lightning-caused fires tended to start most frequently on southeast facing slopes (Figure 6). North, northeast, and east facing slopes tended to have fewer fires than other aspects. Southwestern aspects should have the highest number of fire starts since they are driest. Conversely, northeastern facing slopes are the most mesic aspects and should have the fewest successful fire starts. In general, these theoretical distributions of fire occurrence were supported by the data. However, this hypothesis cannot be tested unless the area covered by each aspect is considered.

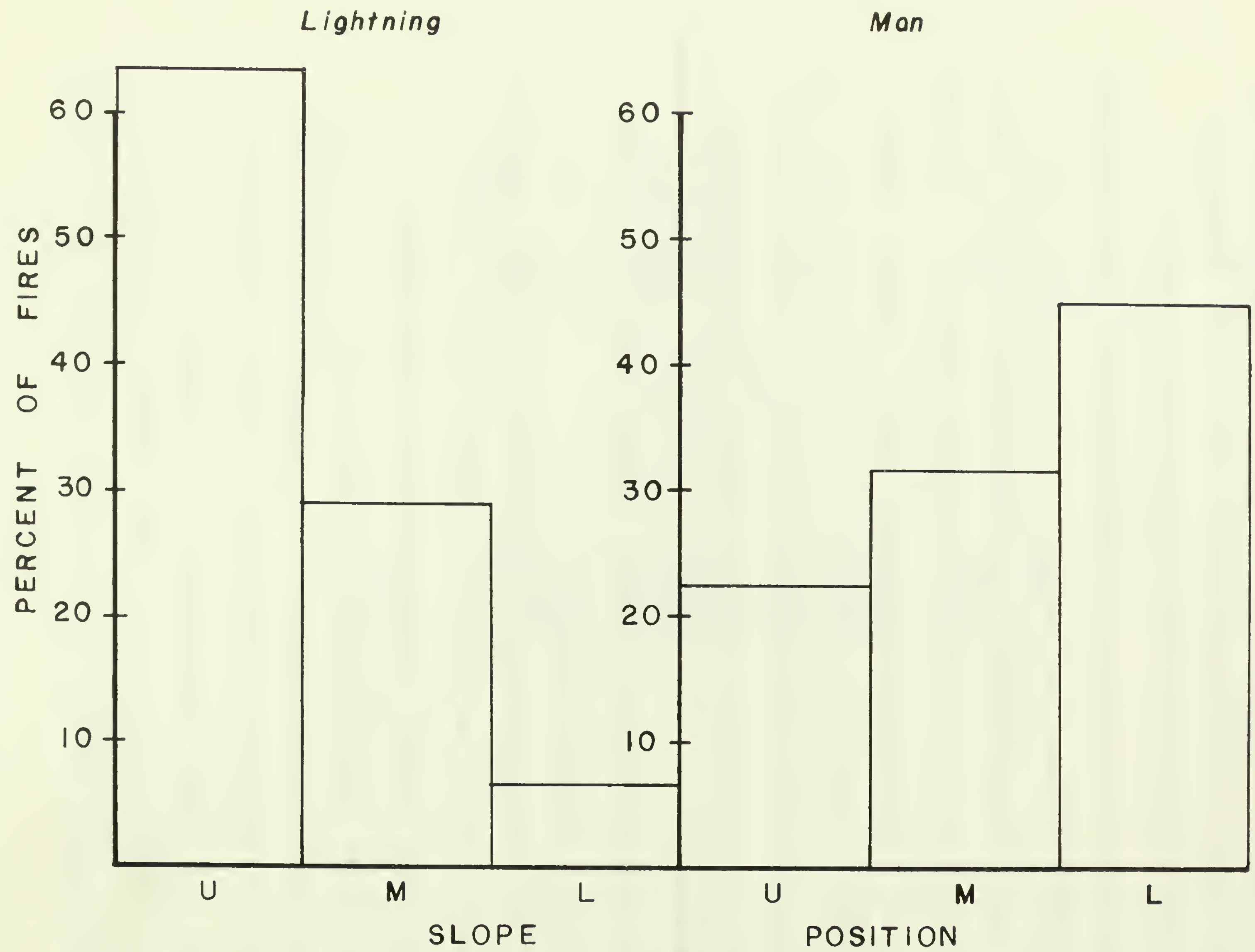

Figure 5. Origin of fires as a function of slope position for man- and lightning-caused fires. Slope positions are indicated by U - upper one-third, M - middle one-third, and L - lower one-third.

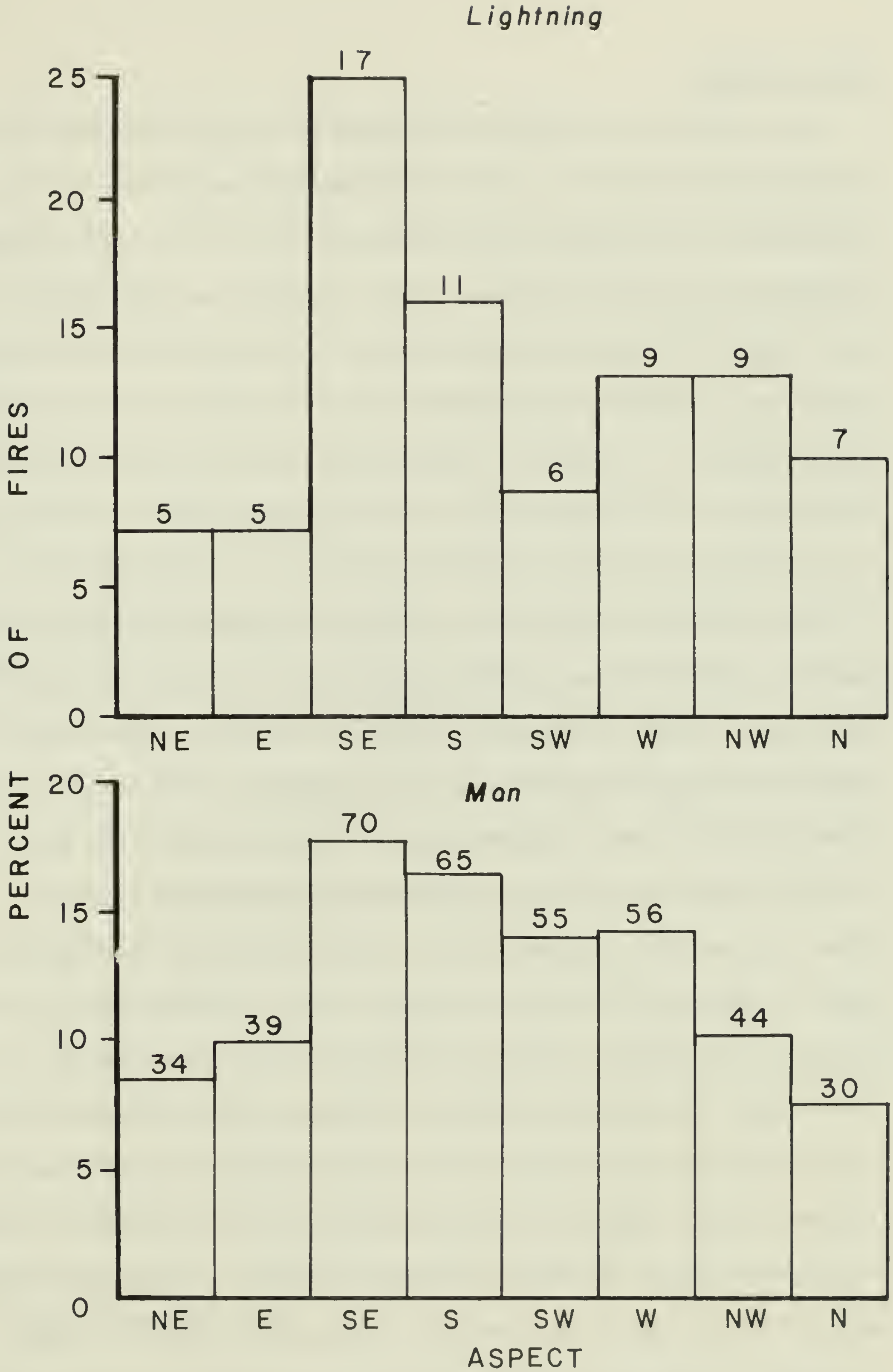

Figure 6. Origin of fires as a function of aspect for man- and lightning-caused fires. The numbers above the histobars indicate the actual number of fires observed.

Fire Rotation

Fire rotation is defined as the number of years required to burn an area equivalent to an area of interest (Heinselman 1973). This definition does not imply each area burns exactly once, but incorporates heterogeneity of fire frequency--some areas may not burn at all, while others may burn many times. Of course, the more heterogeneous the study area, the less representative the fire rotation will be for a given habitat. In spite of these limitations, fire rotation is a useful index to characterize a fire disturbance regime. Fire rotation is calculated by dividing the total area by the area burned per year.

When GRSM was considered as a whole, the man-caused fire rotation was 844 years, and the lightning-caused fire rotation was 30,400 years (Table 1). These calculations, however, included a wide range of habitats in terms of elevation and topography. When the park was divided into 305 meter (1,000 feet) elevational bands, the fire rotation tended to increase with increasing elevation (Table 1). These calculations assumed that if a fire started in an elevational band, it only burned in that elevation band. For many cases, this assumption held true. However, in the case of the 0 meter to 305 meter band, the fire rotation was exceedingly short because a major fire started at that elevation but burned mostly in the 305 meter to 610 meter band. Another problem entered the fire rotation calculation when lands outside the park were not considered as part of the band. Many fires burning at the lowest elevation bands may have burned outside the park and were not considered as part of the band. Many fires burning at the lowest elevation bands may have burned outside the park. In spite of these limitations, the stratification of GRSM into elevation

bands proved useful in reducing heterogeneity.

Another important stratification of the park was made according to topographic position. Unfortunately, there were difficulties in portioning GRSM into topographic units. Two assumptions were made: (1) the fires burned topographic positions in proportion to the number of starts on that position, and (2) the proportion of topographic positions (i.e., upper two-thirds versus middle one-third versus lower one third) were equal. An adjustment was not made to account for the number of fires that started on one topographic position but then burned into another. The final results of the fire rotation calculations are presented in Table 2. As elevation increased, the fire rotation generally increased for both man- and lightning-started fires. For man-caused fires, the fire rotation decreased as one proceeded from upper slopes to lower slopes. At the 305 to 610 meter elevational band, the fire rotation for lower slopes was 180 years, while the fire rotation for upper slopes was 340 years. Middle slopes were intermediate, with a rotation of 265 years. On the other hand, lightning-caused fires had shorter fire rotations on upper slopes. At the 305 to 610 meter elevational band the rotation was 9,400 years on upper slopes and 74,200 years on lower slopes. In terms of a regional influence, lightning fires were almost nonexistent--a purely localized phenomena. These calculations, however, used fire sizes during the suppression era.

Without some knowledge of how large lightning fires will become when total suppression is ended, it was very difficult to predict the

Table 2. Present day fire rotation or mean fire recurrence interval by cause, elevation, and topographic position.

Elevation	Lightning		
	Upper 1/3 Slope	Middle 1/3 Slope	Lower 1/3 Slope
305 - 610	9,400	20,470	74,205
610 - 915	26,610	57,800	209,550
915 - 1,220	10,800	23,400	85,000
1,220 - 1,525	58,075	126,170	457,350
1,525 +	6,854,500	14,890,800	53,979,200
	Upper 1/3 Slope	Middle 1/3 Slope	Lower 1/3 Slope
305 - 610	340	265	180
610 - 915	3,610	2,800	1,930
315 - 1,220	2,860	2,215	1,525
1,220 - 1,525	90,350	69,950	48,185
1,525 +	118,180	91,495	63,030

natural lightning caused fire rotation. Rather than try to give exact estimates, the lightning fire rotation was calculated assuming 5-, 10-, and 20-fold increases in fire size. Fire frequency was assumed to remain at the levels observed between 1940 and 1979. The calculation of "natural" lightning fire rotation was made by dividing the rotations in Table 2 by the factor fires were expected to increase. For brevity, only the fire rotations for the 305 to 610 meter elevational band were presented. Assuming a 5-fold increase in fire size, a rotation of 1880 years on upper slopes was calculated. A 10- and 20-fold increase gave a rotation of 940 and 470 years respectively. Since this was the topographic position and elevation that lightning fires had the most impact, it followed that the fire rotation in other habitats was longer. Accepting the limitations of this model, it appears that lightning fires will probably not maintain large and widespread communities.

DISCUSSION

Fire Cause

Most fires started in GRSM between 1940 and 1979 were caused by man and were incendiary in nature. Barden (1974) observed that man was the primary cause of fire in the Southern Appalachian Mountains between 1960 and 1971. Lightning-started fires tend to burn proportionately less area in GRSM relative to the whole Southern Appalachians. Barden (1974) reported lightning fires burned 14 percent of the total area, but in the present study, lightning fires burned 4 percent of the total area. These differences may have been caused by the numerous, large, man-caused fires which occurred in the 1940's.

Fires in the southern forest region were mostly of incendiary origin

(US Forest Service 1980). Debris burning was second in importance in the southern forest region but third in importance in GRSM. The high portion of smoker fires in GRSM may have been caused by high visitation rates. Throughout the eastern USA, incendiary fires were the leading cause of fires (US Forest Service 1980). Thus, GRSM fits into a larger regional pattern. Lightning-started fires were much more important in the Rocky Mountain and Pacific states, where 20 to 40 percent of all fires were caused by lightning (US Forest Service 1980). Although the incidence of lightning fires was low throughout the Southeast, it was higher than in both the eastern and north central states. The high occurrence of local-started fires in GRSM was not an isolated problem. Haines et al. (1975) reported that most fires in the northeastern and north central states were also set by locals. These fires were often started because of a grudge held against the landholding agency.

Fire Frequency

There was a mean of 63 man-caused and 10 lightning-caused fires per year per million hectares in GRSM between 1940 and 1979. Barden (1974) reported 15 lightning-caused fires per year per million hectares. This indicated GRSM had fewer fires caused by lightning than other regions in the Southern Appalachians. Barden (1974) observed significant variation in fire incidence throughout the Southern Appalachians. In the Cherokee National Forest, lightning started 1.8 times as many fires per unit area as in GRSM. However, Cades Cove Ranger District was similar to the Cherokee National Forest in terms of lightning-caused fire incidence and indicated that the Cades Cove Ranger District represented a very different climatic zone in terms of lightning from the rest of GRSM.

Fire Size

Compared to the distribution of fires in size classes for the southern forest region, GRSM had proportionally more class A, D, and E fires than expected and fewer class B than expected. The mean fire sizes found by Barden (1974) were larger for lightning-caused fires but smaller for man-caused fires. The larger mean size found in the present study was probably due to frequent and large man-set fires in the 1940's. There has also been a general increase in mean lightning size for each decade. The mean fire sizes of both causes were calculated for the 1960's and were comparable to those reported by Barden (1974).

The largest lightning fire reported by Barden (1974) burned 33 ha. The first lightning fire that was not extinguished by management in GRSM burned 44.5 hectares. This indicated a "let burn" policy will increase the mean lightning-caused fire size but to an unknown degree.

Fire Season

The results of the present study concerning fire season was consistent with those reported by Barden (1974). The bimodal distribution of man-caused fires corresponds well to the seasonal variations in precipitation observed by Stephens (1969) in the central portion of GRSM. The peak in lightning-caused fires occurred during the late spring drop in precipitation. The high occurrence of lightning fires at this time may be caused by the onset of brief thunderstorm activity, which ignites fuels but does not moisten them to the point of being unable to burn. The peak month for lightning activity was July (Visher 1961), and yet the incidence of lightning

fires dropped during this month. Perhaps the increase in precipitation during July limits the number of lightning strikes that successfully ignite fuels.

The biomodal distribution of man-caused fires observed in GRSM was quite typical for southern forests in general. Haines et al. (1975) found that, in southern forest, fire seasons tended to be bimodal, while northcentral and northeastern forests had one fire season between May and July. A summer fire season was also typical for the Rocky Mountain states.

Effect of Elevation

The number of lightning- and man-caused fires decreased with elevation in both the present study and the one conducted by Barden (1974). Barden (1974) attributed the decrease in lightning fires with increased elevation to the greater number of ridgetops at lower elevations. However, this theory assumes there are more ridgetops at lower elevations. Other factors tend to change with elevation. Precipitation and cloudiness increase with elevation. Fuel types differ, and temperature decreases with elevation. All these factors combine to make a lightning strike less apt to ignite a fire at higher elevations.

Although seasonal variation in fire occurrence along the elevation gradient were not examined here, Barden (1974) found significant differences between seasons in the incidence of lightning-caused fires along the elevation gradient.

Effect of Topography

Approximately three-fifths of all lightning fires started on the upper one-third of slopes in the present study. Barden (1974) found slightly over one-half of the lightning fires started on this topographic position in the Southern Appalachians. Perhaps the discrepancies in years examined and minor regional patterns caused these differences. The topographic distribution of lightning fire starts in both studies contrasts strongly with the distribution of fires started by man, which tend to start on lower and middle slope positions.

The starting point of a fire may have a large impact on fire spread rate, intensity, and its impact on a forest. Fires starting at the base of a ridge will be head fires, while those starting on a ridgetop will be backing fires. In general, head fires tend to spread quickly, kill by convective heating, and are fairly inefficient in consuming fuel. On the other hand, backing fires have low spread rates, kill by girdling at ground level, and efficiently consume fuels. Barden (1974) attributed the main difference in behavior of man- and lightning-caused fire behavior to weather.

Aspect was an important factor in determining the location of a fire's origin. Southeast-facing slopes were the most apt and northern aspects were least apt to have fire starts. These differences could be due to the areal extent of each aspect, or a function of moisture, or a function of forest cover, or some combination of these factors. Barden (1974) found that pine forests in Cherokee National Forest were more apt to have lightning fires than predominately hardwood forests. No data on forest cover existed in GRSM to make a comparison. However, since man-caused fires start on lower to middle slopes, they are apt to

burn in hardwood forests. A large portion of lightning fires will tend to start on southern-facing upper slopes, a topographic position where pine forests dominate. It would be interesting to test the hypotheses suggested by Mutch (1970): fire dependent communities promote fires by increasing fuel flammability.

Improvement in Data Base

Two very important factors that were not considered in this study were the effect of vegetation cover and fire severity. An examination of the vegetation descriptions in the fire control records indicated that they were of little value. A vegetation map would be a useful resource management tool in terms of describing burned forest types.

In addition to mapping the origin of the fire, it is important to map areas that are severely burned. This data would allow a better assessment of fire's impact in GRSM. The relative importance of fuel, topography, and weather in determining fire severity could also be assessed. Many species require a severe fire to reproduce successfully. Data on severe fire patches would allow a more accurate assessment of fire impacts on the distribution of these species.

There are useful categories which are not required on present forms but their inclusion would be very informative. For example, a category for visitors under "reporter of fire" would be very useful. This is especially relevant since the category "other" composed over half of the recent reporters but tells little about what type of person is actually involved.

Today's Fire Regime in a Historical Perspective

Fire between 1940 and 1979 was an unimportant disturbance in terms of rotation, recurrence, severity, and so on. Fire was more widespread in earlier periods of GRSM's history. These changes throughout time have been caused primarily by man.

Little quantititive data exists on the use of fire by pre-Columbian man. Accounts indicate Indians used fire extensively to hunt, gather nuts, enhance berry crops, and clear the forest of undergrowth (Day 1953; Goodwin 1972).

The impact of Euro-American man has been generally documented in GRSM (Ayres and Asher 1905, Harmon 1980b, Heritage 1939, Lambert 1958, Shields 1977). Harmon (1980) found yellow pine forests in the western portion of GRSM were burned once every 12 years on the average between 1850 and 1940. The fire rotation for the same period was estimated to be as short as 3 years and as long as 48 years. Most of these fires were probably caused by man. The observations of Ayres and Ashe (1905) at the turn of the century indicate differences in fire occurrence between watersheds. These patterns were quite similiar to the ones found in the present study. For example, Cades Cove and the surrounding vicinity had the highest occurrence of fires in 1900. In contrast, Big Creek and Cataloochee had very little burning. These comparisons indicate there may be climatic causes of the observed geographical differences.

Perhaps man's most destructive impact on the GRSM landscape occurred between 1910 and 1930. During these two decades, extensive fires raced through recently clear-cut watersheds. Unlike the frequent cool surface fires set by settlers and Indians, the logging era fires were very severe.

SUMMARY AND CONCLUSIONS

The character of man-caused fires between 1940 and 1979 has differed greatly from those started by lightning. Man-caused fires have been more numerous and burned a larger area than lightning-caused fires. Man-caused fires were also more apt to start at a lower elevation, nearer to park boundaries and on lower slope positions than lightning-caused fires. Lightning-caused fires started during spring and summer, but man-caused fires tended to start during spring and fall. Differences between man- and lightning-caused fires emphasized that each cause tended to have different impacts on the ecology of GRSM.

Fire occurrence in GRSM has differed greatly between ranger districts, elevation, and aspects. Fire incidence decreased with elevation, regardless of cause, and no fires have been observed since 1940 above 1,830 meters. The Tennessee portion of GRSM had a greater number of fires than the North Carolina portion. Based on the incidence of lightning-caused fires, the Cades Cove Ranger District appeared to be a unique unit in GRSM (and similar to zones outside the park) with high lightning fire incidence. Both man- and lightning-started fires originated most frequently on southeast- to west-facing slopes.

Our understanding on the impact of fires in GRSM could be improved greatly by adding information on vegetation cover and fire severity. Mapping of fire "hot spots", heavy fuel accumulations, and fire perimeter growth would provide data to further compare the impacts of man-caused versus lightning-caused fires.

Finally, management has significantly reduced the impact of fire

in GRSM relative to historical periods before the establishment of GRSM. By increasing the occurrence of fire, Indians and Euro-American man had the opposite effect on the fire regime. Once again, man will change the fire regime by allowing some lightning-caused fires to burn. However, data from the present study indicated that lightning-caused fires will influence less area than man-caused fires and will probably not maintain fire dependent forest covers except in very localized situations. At the present time, it is crucial to determine to what extent the present forest patterns are due to Indian burning and to decide if it is appropriate to manage specifically for that influence.

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APPENDIX

Table 3. Causes of man-ignited fires in Great Smoky Mountains, 1940 to 1979.

	FIRES	
Cause	Number	Percent
Campfire	69	12.9
Smoking	133	24.9
Debris burning	91	17.0
Incendiary	167	31.3
Equipment use	2	0.3
Railroad	1	0.2
Children	13	2.4
Miscellaneous	52	9.7
Unknown	6	1.1
TOTAL	534	

Table 4. People involved in fire starts for the period, 1940 - 1979.

People	FIRES Number	Percent
Landowners	3	0.6
Lease	1	0.2
Private Services	25	4.7
Public Employees	9	1.7
Permanent Local	229	42.9
Seasonal Local	2	0.4
Visitors	119	22.3
Other	91	17.0
Unknown	51	9.6

Table 5. Origin of fire in relation to GRSM boundary.

Origin	Lightning		Man	
	Number	Percent	Number	Percent
In GRSM	75	89	300	56
Leased lands in GRSM	0	0	4	0.7
Outside GRSM but entered	3	4	67	12
Outside GRSM	4	5	152	28
Other	0	0	2	0.4
Unknown	2	2	9	2

Table 6. Number and area burned by man and lightning in GRSM for the years 1940 to 1979.

	Number		Area (hectares)	
Year	Man	Lightning	Man	Lightning
1940	24	6	680	12
1941	47	4	1,007	2
1942	32	1	1,448	
1943	11	4	857	3
1944	8	1	245	
1945	18	2	180	1
1946	12	0	31	0
1947	11	5	528	7
1948	10	2	35	1
1949	5	3	4	2
Decade sub-total	178	28	5,016	30
1950	9	0	11	0
1951	3	1	1	33
1952	46	10		14
1953	13	3	54	
1954	9	5	19	1
1955	11	1	444	
1956	11	5	30	47
1957	19	5	17	
1958	9	4	47	9
1959	20	1	21	1
Decade sub-total	150	35	2,423	105

Table 6. Continued.

	Number		Area (hectares)	
Year	Man	Lightning	Man	Lightning
1960	13	1	38	1
1961	16	0	29	0
1962	1	7		42
1963	9	1	15	
1964	9	3	23	7
1965	13	2	23	4
1966	8	0	2	0
1967	12	0	222	0
1968	9	1	11	2
1969	4	1	59	
Decade sub-total	90	16	422	56
1970	5	0	2	0
1971	9	2	186	32
1972	7	0	10	0
1973	6	0	5	0
1974	10	1	32	1
1975	9	0	182	0
1976	16	1	540	44
1977	17	1	158	5
1978	28	0	427	0
1979	9	0	9	0
Decade sub-total	116	5	1,551	82
TOTAL	534	84	9,412	274

indicates area less than 0.5 hectares

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